Impacts of Feral Livestock on Island Watersheds[1]

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Abstract: We assessed the effects of overgrazing by feral sheep on watersheds on Santa Cruz Island, California. Overgrazing had a marked effect on stream flow; flows were much greater in overgrazed than in lightly grazed watersheds early in the rainy season, but the difference vanished later in the season. This pattern can be explained by reduced infiltration and increased surface runoff of rainfall in overgrazed areas. Thus, feral livestock may affect island species not only directly by grazing and trampling, but also indirectly by altering hydrologic processes and therefore species that are dependent on these processes.

LIVESTOCK GRAZING CAN have dramatic effects on watershed systems (Mwendera and Saleem 1997). Grazing reduces plant density, ground cover, and litter (Naeth and Chanasyk 1996); when vegetation cover declines, soil bulk density increases and organic matter content and aggregate stability decrease, resulting in decreased rate of water infiltration and increased sediment production (Mwendera and Saleem 1997). Simulations showed that runoff and sediment yield from rainfall increased with increased grazing intensity and reduced ground cover (Johnston 1962). As a result, grazing in many sensitive watersheds is restricted (Holechek et al. 1989).

Watersheds on islands may be particularly vulnerable to the effects of grazing, especially by feral livestock. Because island ecosystems typically lack large herbivores, endemic plants lose their defenses against herbivory; consequently, the introduction of livestock can be especially devastating to island vegetation (Bowen and Van Vuren 1997). Further, grazing by feral livestock is often unrestricted on islands, and densities can reach high levels (Coblentz 1978, Van Vuren and Coblentz 1987, Parkes 1993).

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Feral sheep and goats exist on numerous islands worldwide (Rudge 1984). Their impacts on vegetation and soils through grazing and trampling have been documented (Coblentz 1978, Van Vuren and Coblentz 1987), but resultant effects on island watersheds have never been studied. Our purpose in this study was to determine the effects of overgrazing by feral sheep on stream flows in watersheds on Santa Cruz Island, California. We hypothesized that overgrazing would alter stream flows, presumably by increasing surface runoff following major winter storms.

Study Area

Santa Cruz Island, located 40 km south of Santa Barbara, is 39 km long and 3–11 km wide (249 km^2). An east-west system of interior valleys, dominated by the large Central Valley, bisects the island longitudinally along a geological fault. The major drainage of Santa Cruz Island has its headwaters in Griffith Canyon, on the south slope of Picacho Diablo, the highest peak on the island (750 m), and drains east through the Central Valley. Topography is rugged and slopes may exceed 30°. Climate is an oceanic, Mediterranean type characterized by hot, dry summers and mild, wet winters. Most of the 52 cm average annual precipitation falls from November through April. Vegetation on the island is diverse, with many endemic species (Junak et al. 1995). Grassland, chaparral, oak woodland, and coastal sage scrub communities cover 89% of the island (Minnich 1980).

Sheep ranching began on Santa Cruz Island during the 1850s, but ranching was

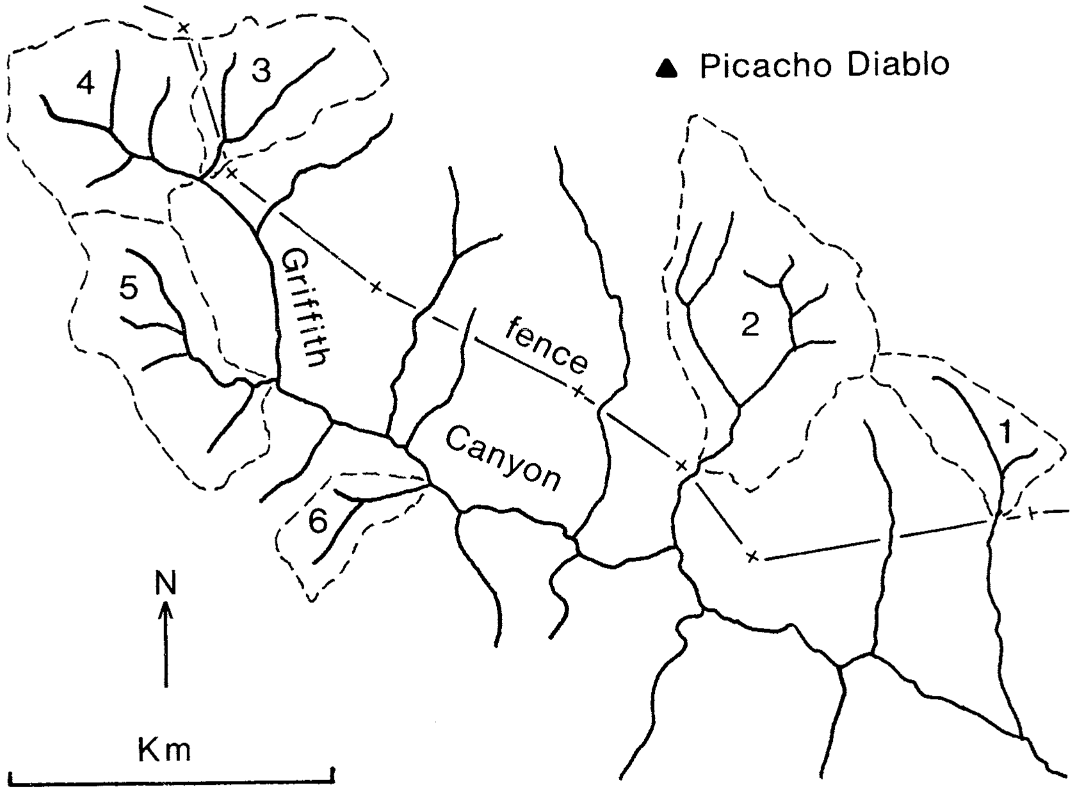

FIGURE 1. Map of the study area on Santa Cruz Island, showing the six watersheds in Griffith Canyon and the fence that divided areas of high sheep density (north of the fence) and low sheep density (south and southwest of the fence).

abandoned and the sheep became feral (Van Vuren and Coblentz 1989). At the time of our study the island supported at least 20,000 sheep (Van Vuren and Coblentz 1989), but density of sheep varied spatially because of past control efforts. A fence extended in a generally east-west direction across the south slope of Picacho Diablo; because of sheep control south of the fence, tributaries entering Griffith Canyon from the south and southwest supported low densities of feral sheep (0.2/ha), but those entering from the north supported densities about 10 times greater (2.1/ha), which is extraordinarily high by any measure (Van Vuren and Coblentz 1989).

MATERIALS AND METHODS

For our study we selected six tributaries of Griffith Canyon that were similar in physical characteristics (e.g., geologic substrate, soils, slope), area, and plant community, but differed in grazing history (Figure 1). All six watersheds were underlain by the same geologic formation, the Griffith Canyon Member of the Santa Cruz Island Volcanics, which supported haploxerol soils 30–90 cm thick. Soil depth, however, was reduced by erosion in areas that had been overgrazed by feral sheep (Brumbaugh 1980, Butterworth et al. 1993). Slopes, which were similar among tributaries, ranged from 15 to 30° but were typically 20–25°. Vegetation throughout the area was mostly grassland, with some scattered patches of coastal sage scrub and a few oaks (*Quercus* sp.). Three tributaries supported low densities of sheep and were covered with dense grassland vegetation that showed little evidence of disturbance by sheep, with few, if any, areas of denuded soil. The other three tributaries supported high densities of sheep and were characterized by severe overgrazing; herbaceous vegetation was mostly or completely consumed, and denuded soil was prevalent (Van Vuren and Coblentz 1987). Drainage area averaged 29.0 ha in overgrazed watersheds and 26.6 ha in lightly grazed watersheds.

Following the first three major storms of winter 1979–1980, we measured stream flow in each tributary 6–12 hr after each storm ended, using standard procedures (Gordon et al. 1992:157), on 9 January (6.4 cm), 11 January (3.2 cm), and 17 February (>7.5 cm) 1980. Because we could not measure flows in all six tributaries simultaneously, we randomized the order among tributaries after each storm to avoid bias. For each tributary, a section of stream at the mouth was selected that was relatively straight and uniform in gradient and shape. Stream cross section was determined by measuring water depth at 10-cm intervals. Stream velocity was determined by calculating the mean of five replicated measures of the time required for a cork float placed at the center of the stream to travel 1 m. We multiplied cross-sectional area by velocity to obtain stream flow (liters/second). In one lightly grazed watershed, stream flow after the first two storms was too low to measure using cross section and velocity, so we measured the time required to fill a 1-liter bottle placed beneath a waterfall that permitted capture of the entire flow. Watershed size varied, so to standardize our comparisons we calculated stream flow per unit area (liters/minute/hectare).

TABLE 1

Stream Flow and Drainage Area in Six Watersheds on Santa Cruz Island after the First Three Storms of Winter 1979–1980

		Stream flow (liters/second)		
Watershed	Area (ha)	Storm 1	Storm 2	Storm 3
1	16.1	4.7	40.6	26.0
2	50.0	24.0	34.0	38.2
3	20.8	16.1	30.9	28.9
4	34.5	4.5	30.5	84.9
5	32.7	1.4	11.7	33.1
6	12.5	0.2	0.7	9.5

Note: Three watersheds (1–3) were overgrazed by feral sheep, and three (4–6) were lightly grazed. Watershed numbers correspond to numbered locations in Figure 1.

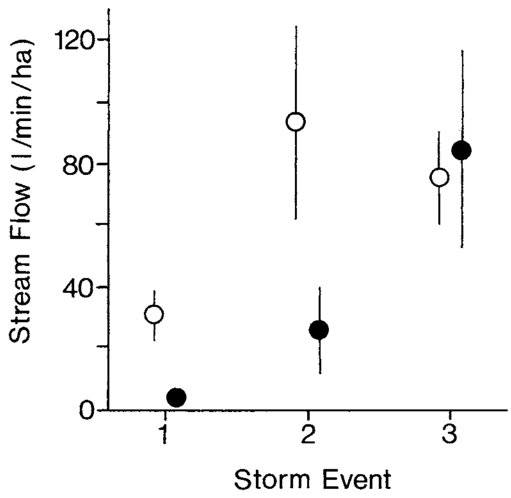

FIGURE 2. Stream flows, corrected for watershed size (liters/minute/hectare), in lightly grazed (shaded circles) and overgrazed (open circles) watersheds on Santa Cruz Island after the first three storms of winter 1979–1980. Means and associated standard errors are shown.

RESULTS

Stream flow after the three storms varied greatly among watersheds, in part because of differing grazing histories, but also because of variation in drainage size (Table 1). When stream flows were corrected for watershed area, a pattern emerged. Stream flows after the first storm of the winter averaged about eight times greater in overgrazed watersheds than in lightly grazed watersheds (Figure 2).

Following the second storm flows increased in all watersheds but remained substantially greater in those that were overgrazed. Flows after the third storm remained high in overgrazed watersheds; surprisingly, however, flows in lightly grazed watersheds increased dramatically and actually slightly exceeded those in overgrazed watersheds.

DISCUSSION

Santa Cruz Island had not received substantial precipitation since the preceding spring, so the soil probably was very dry. Nonetheless, despite the high water-absorbing capacity of the soil, the effects of overgrazing on increased stream flows were evident after the first storm of the winter. This difference between overgrazed and lightly grazed areas persisted through the second storm but vanished after the third storm, probably because surface runoff in lightly grazed areas was augmented by groundwater that had percolated through the soil since the first two storms, an effect that would be diminished in overgrazed areas where water infiltration into the soil was greatly reduced. Our results are consistent with those of studies on the mainland, which showed that heavy grazing by livestock resulted in decreased rates of infiltration and increased runoff (Sharp et al. 1964, Gifford and Hawkins 1978).

High densities of feral sheep have resulted in the denudation of much of Santa Cruz Island through grazing and trampling (Van Vuren and Coblentz 1987) and led to increased soil disturbance, compaction, and erosion (Brumbaugh 1980, Van Vuren 1982). Our results show that stream flows have been affected as well, with likely impacts on native species, many of which are endemic. Increased surface runoff means accelerated soil erosion and reduced water content of the soil, both of which impact plants. Further, grazing-induced changes in timing and magnitude of stream flows have impacts on stream-associated species such as riparian plants and aquatic vertebrates and invertebrates.

Island ecosystems support unique biotic communities rich in endemic taxa (Mueller-Dombois 1981); thus they are of special biological importance. Our findings have implications for the conservation of these ecosystems; feral livestock affect endemic species not only directly through grazing and trampling, but also indirectly by altering hydrologic processes. These impacts may be especially pronounced on islands with deeply dissected terrain and variable rainfall with a pronounced dry season (Daly and Goriup 1987), which characterizes Santa Cruz Island and many other islands as well.

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